

The Industrial / Societal Bullwhip Effects and Supply Chain Performance

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⟨Abstract⟩

The objective of this paper is to describe the construct of bullwhip effect beyond supply chains, namely at industrial and societal levels. The author provides a conceptual discussion of the bullwhip effect – its derivation is extended, and the positioning of the construct is broadened. The bullwhip effect has been explored within intra-organisational and inter-organisational supply chains. A broader descriptive framework is introduced, one that positions the bullwhip effect construct at industrial and societal levels. A conceptual framework is provided that bridges the interface between the micro and macro environments of the bullwhip effect construct, but further conceptualization is required. The introduced derivation and positioning of the bullwhip effect construct reveal a number of research potentials. A principal one is that the exploration of the construct may consider the industrial and/or the societal environment when the bullwhip effect is studied in supply chains. The extended derivation and broadened positioning of the bullwhip effect in the overall environment is of interest to practitioners. It stresses the importance of contextual factors in operative, tactical and strategic supply chain performance. The principal contributions are: a) an interface between micro and macro levels in supply chain performance contributing to an extended derivation of the bullwhip effect; b) a typology of the bullwhip effect contributing to broadening the positioning of the same construct; c) the bullwhip effect being seen as two-way view construct at the micro level and d) a framework of managerial implications. Most important of all is that the causes and effects of the bullwhip effect have been addressed in a wider context that so far has been underestimated in literature.

Key words: Bullwhip effect, supply chain performance, industrial, societal, two-way, micro, macro.

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产业/社会的牛鞭效应与供应链绩效

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<摘要>

本文的目的是在产业和社会的层面上重新定义供应链牛鞭效应的概念。作者对牛鞭效应进行了概念性的分析，包括对其外延和内涵的扩展。在组织内部和组织之间供应链的范围内已经对牛鞭效应开展了研究，本文在产业和社会这一更广泛的层面上提出了牛鞭效应的研究框架。这一概念框架有助于联系牛鞭效应的微观和宏观外部环境。该框架的基本原则是供应链牛鞭效应的研究要考虑产业和社会环境，这一框架更强调在操作层面、战术层面和战略层面的供应链绩效中环境因素的重要性。本研究的重要贡献体现在：1) 扩展了牛鞭效应的内涵，把供应链的微观和宏观层面联系起来；2) 建立了牛鞭效应的理论模型并拓展了这一概念；3) 提出了管理建议。最为重要的是在更广泛的背景下探讨了牛鞭效应的成因和影响。

关键词：牛鞭效应；供应链绩效；产业；社会；双向；微观；宏观

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Introduction

Lee, Padmanabhan and Whang (1997a) conclude that the variance of orders may be larger than that of sales, and that distortion tends to increase as one moves upstream in supply chains. This supply chain performance is referred to in literature as the "bullwhip effect" (Chen et al., 2000). The term itself was in fact coined by Lee, Padmanabhan and Whang (1997b). The bullwhip effect describes how the supply chain performance tends to be lower upstream than downstream, e.g. it is caused by factors such as deficient information sharing, insufficient marketing data, deficient forecasts or other uncertainties (e.g. Lee and Billington, 1992; Towill, 1996). Fransoo and Wouters (2000) mean that the bullwhip effect refers to increasing variability of demand further upstream in a supply chain, and conclude that the theory of measurement of the bullwhip effect in a practical setting -

such as supply chain performance - has received limited attention.

Further upstream is a relative, and to some extent questionable, measure of the bullwhip effect construct. For example, Svensson (2003) introduces the term "reversed bullwhip effect" (i.e. decreased supply chain performance downstream caused upstream) as opposed to the traditional term "bullwhip effect" (i.e. decreased supply chain performance upstream caused downstream). In addition, Svensson (2005) discusses different facets of the bullwhip effect. One is that the bullwhip effect should be seen as a relative measure between supply chains. The origin of the bullwhip effect may go beyond the supply chain itself - it may also be caused at or derived from industrial and societal levels of the environment.

There is still a need for further derivation and positioning of the construct

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beyond value chains and value systems (Porter, 1985) – in extension, beyond supply chains. The bullwhip effect has been explored at the micro level of environment, rather than placed in macro level context. In fact, when the bullwhip effect has been explored, the environment of industries and societies has been ignored. There is a need to bridge the gap between the micro and macro levels of the bullwhip effect construct, namely on the one hand the different levels of supply chains, and on the other the industrial and societal levels of the environment. *Therefore, the objective is to describe the bullwhip effect construct at industrial and societal levels.*

Frame of Reference

Initially, this section positions the construct of the bullwhip effect and its roots. A practical flavour is also incorporated. Furthermore, it structures previous research approaches of the bullwhip effect in terms of explored echelons in supply chains, and thus provides an overview of causes and effects on supply chain performance. Finally, it positions the bullwhip effect

construct at both micro and macro levels.

Positioning and Roots

The frame of reference of the bullwhip effect construct may be traced and connected to different historical topics, such as the functionalist theory of marketing (Alderson, 1965), industrial dynamics (Forrester, 1961), the total cost concept (Culliton, Lewis and Steele, 1956), and the institutional school of marketing (Weld, 1916). The theoretical framework is also underpinned by the value chain and value system constructs (Porter, 1985), the principle of postponement (Alderson, 1950), and the principle of speculation (Bucklin, 1965).

Ever since its inception, Supply Chain Management (SCM) has been of interest in literature for many years (e.g. Oliver and Webber, 1982; Jones and Riley, 1985 and 1987; Houlihan, 1985 and 1987; Snowdon, 1988). Stock (2000) states that SCM is an influential ingredient in today's literature and thinking in the field of logistics. The synchronisation of business operations between multiple relationships in marketing channels is often referred to as SCM (Lambert, Cooper and Pagh, 1998).

Companies' atomistic considerations (i.e. sub-optimisation of business operations) in supply chains cause the bullwhip effect to occur. The co-operation and co-ordination between companies' business operations is necessary to maximise supply chain performance. Otherwise, the bullwhip effect might affect negatively the overall outcome of the supply chain.

Alderson (1957 and 1965) recognises the interdependence between companies' business operations in marketing channels. Forrester (1958) also acknowledges the linkages between business operations in marketing channels, e.g. in terms of the interactions between the flows of information, materials, money, and manpower, and capital equipment. Forrester (1961) discusses dynamics in the business environment and writes that industrial dynamics view business as an integrated system. Furthermore, Weld (1916) stresses the importance of addressing the distribution channel as a whole. SCM addresses the supply chain from the point-of-origin to the point-of-consumption (Mentzer et al., 2001; Lambert, 1992; Cavinato, 1992). Svensson (2002) argues that there is a necessity to extend SCM towards other supply chains. Furthermore, SCM requires co-operation and co-ordination

between companies' business operations in supply chains (Xu, Dong and Evers, 2001; Holmström, 1997). Otherwise, the performance tends to be deteriorated as it moves upstream in the supply chain (Towill, 1996; Lee and Billington, 1992).

In fact, practitioners and consultants have long striven to deal with the bullwhip effect, e.g. in the automotive, textile, and retail industries. In the automotive industry the term Just-In-Time (e.g. Sugimori, Kusunoki, Cho and Uchikawa, 1977; Toyoda, 1987) has been used, while in the textile and retail industries the terms Quick Response (e.g. Stern, El-Ansary and Coughlan, 1996; Fernie, 1994) and Efficient Consumer Response (e.g. Kurt Salmon Associates, 1993) have been applied. These terms, or business philosophies, aim at optimising the supply chain performance - and in the end improve profitability, reduce costs and increase the overall efficiency of the supply chain beyond judicial boundaries as a whole.

Previous Research – Approaches

The bullwhip effect may be derived from the dependencies that exist between actors, activities and resources at both

micro and macro levels. Furthermore, these dependencies may implicitly or explicitly influence the supply chain performance at both levels.

Principally, previous research of the bullwhip effect has considered inter-organisational supply chain performance, such as two-echelons between companies (e.g. Yu, Yan and Cheng (2001; Chen, et al, 2000; Fransoo and Wouters, 2000; Kelle and Milne, 1999), or three-/multi-echelons between a sequence of companies (e.g. McCullen and Towill, 2001; Jacobs, 2000; Metters, 1997; Lee, Padmanabhan and Whang, 1997a; 1997b), or intra-organisational echelons, such as companies inbound and outbound logistics flows (Svensson, 2003). Recently, Svensson (2005) refined and redefined the bullwhip effect as the relative performance in and between value chains and value systems.

Supply Chain Performance – Causes and Effects

Sterman (1989) describes that the misperceptions about information may cause human behaviour to over-react. Flaws in available information at

operative, tactic and strategic levels may trigger speculative corporate decision-making. These may be triggered by factors at the macro level, such as prognostic scarcity and economic cycles - i.e. disharmony between supply and demand of materials and components - nationwide and/or worldwide. Supplychain performance in the micro environment is therefore troublesome to handle in a managerial context without knowing the essentials of the macro environment.

Lee, Padmanabhan and Whang (1997a) state that the weak supply chain performance could be the effect of excessive inventory, poor product forecasts, insufficient or excessive capacities, poor customer service due to unavailable products or long backlogs, uncertain production planning (i.e. excessive revisions), and high costs of corrections, such as for expedited shipments and overtime. Lee, Padmanabhan and Whang (1997b) identify four major causes for the bullwhip effect, namely demand forecast updating, order batching, price fluctuation, and rationing and shortage gaming. The bullwhip effect can be mitigated by reduced lead times, revision of re-ordering procedures,

limitations of price fluctuations, and the integration of planning and performance measurement (Lee and Billington, 1992; Towill, 1996; Fransoo and Wouters, 2000). Accordingly, the causes and the effects of the bullwhip effect are mainly rooted at a micro level of the environment.

Baljko (1999) writes that the bullwhip effect in the supply chain may be eliminated through measures such as: sharing knowledge with suppliers and customers to better gauge demand, co-operating with supply chain partners to determine what information is causing an over-reaction, and making use of internet-enabled technology and the application of the web to speed communications and improve response time. Lee, Padmanabhan and Whang (1997a) develop a typology, based upon the causes of the bullwhip effect and the remedies to discuss ways of controlling the bullwhip effect. Chen et al. (2000) illustrate that the bullwhip effect can in part be decreased by centralising demand information. McCullen and Towill (2001) show from supply chain modelling and dynamic simulation four material flow principles, which can be used to reduce the bullwhip effect, namely a control

system, time compression, information transparency, and echelon elimination. Kelle and Milne (1999) conclude that the negative effect of high variability and uncertainty can be decreased by small but more frequent orders. Metters (1997) indicates that the importance of the bullwhip effect for a company differs greatly depending upon the specific business context. Fransoo and Wouters (2000) introduce a method to document and define various ways of measuring the bullwhip effect. Yu, Yan and Cheng (2001) argue that supply chain partnerships can mitigate deficiencies associated with decentralised control and reduce the bullwhip effect. Xu, Dong and Evers (2001) show that the bullwhip effect of order releases and amplifications of safety stock increase within the supply chain even when level demand patterns with no trend and seasonality are stressed.

Consequently, the preventions of supply chain performance to manage the bullwhip effect are also stressed at a micro level of the environment - as well as the causes and the effects. Furthermore, there is an assumption that the origin of weak performance is initiated in downstream echelons of supply chains, rather than

possibly being triggered in upstream echelons (i.e. a so-called reversed bullwhip effect), or that it may be rooted at the macro level of the environment (i.e. so-called industrial and societal bullwhip effects).

The next section contributes to discuss the industrial and societal environment of the bullwhip effect. As such, it moves beyond the refinement and re-definition by Svensson (2005) where it is conceptualised as a relative performance measure between supply chains.

The Industrial and Societal Bullwhip Effects

This section will derive and position the construct of the bullwhip effect at industrial and societal levels. In the first place, it will describe it at micro and macro levels. In the second place, it will describe the interface between industrial and societal levels. Finally, an extended derivation and broadened positioning of the construct is introduced, as well as a two-way view of it.

From Micro to Macro

In literature, the construct of the bullwhip effect is primarily explored and conceptualised at the micro level of corporate environment. For example, Svensson (2003) describes the construct at an internal micro level (see Figure 1) - that is, it is applied in *intra-organisational* echelons, such as companies' inbound and outbound logistics flows. Others apply it at an *external micro level* (see Figure 1) - that is, it is applied in *inter-organisational* echelons, such as two-echelons between companies (e.g. Yu, Yan and Cheng (2001; Chen, et al, 2000; Fransoo and Wouters, 2000; Kelle and Milne, 1999), or three/multi-echelons between a sequence of companies (e.g. McCullen and Towill, 2001; Jacobs, 2000; Metters, 1997; Lee, Padmanabhan and Whang, 1997a; 1997b). Svensson (2005) also conceptualises the construct at an *external micro level*, and touches or crosses implicitly the borders to the *macro level* of the bullwhip effect (see Figure 1).

Lee, Padmanabhan and Whang (1997a) conclude that the bullwhip effect results from the rational decision-making between the actors in supply chains (i.e. inter-organisational echelons). This rational decision-making might also be based upon the relationship between actors within

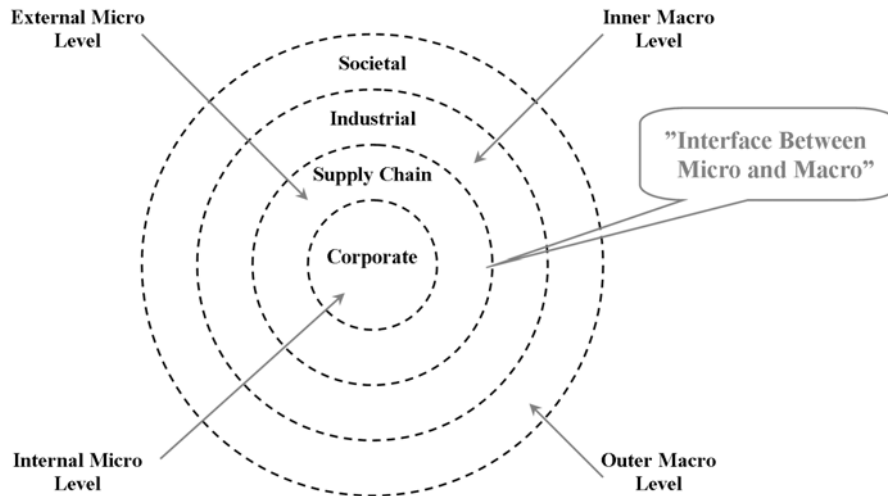


Figure 1. The Interface between Micro and Macro Levels.

companies (i.e. intra-organisational echelons), such as the actors in charge of business operations dealing with procurement and physical distribution (Svensson, 2003).

The common denominator between different sources in literature and others is that they ignore the process of rational decision-making in companies' operative, tactical and strategic supply chain performance may be influenced by the industrial environment. The industry is in turn influenced by other industries and the societal environment. The societal environment does not equal (or stop at) national boundaries, but it is interconnected to other societies and countries both near and far. For example, the American economy impacts the societal

environment of most Western countries. So, in extension the postponement (Alderson, 1950) or speculation (Bucklin, 1965) of operative, tactical and strategic supply chain performance may be derived from the environment of the industry and the society (the latter in a wide sense). In some circumstances the outcome of supply chain performance leads to higher levels of inventories at different stocking levels (i.e. speculation), while in others it leads to lower levels of inventories (i.e. postponement). Accordingly, the process of rational decision-making in operative, tactical and strategic supply chain performance may be influenced by the environments at both micro and macro levels.

Interface between Micro and Macro Levels

The current view of the bullwhip effect in supply chains in literature is mainly restricted to the supply chain performance at the micro level of the environment. In fact, inventory management is taking place at this level, but the cause of supply chain performance may not necessarily be traced to it. The effect is often visualised at this level, but it may also be at the macro one. On the one side, the operative and tactic supply chain performance is influenced and dependent upon happenings at the micro level. On the other side, the happenings at the macro level also influence the supply chain performance, which in turn leads to the strategic outcome possibly being dependent upon this level. Therefore the bullwhip effect should consider the causes and effects at both micro and macro levels of the environment.

Figure 1 illustrates the crucial *interface* between micro and macro levels of the bullwhip effect in supply chain performance. The micro level of supply chain performance consists of two levels, namely: a) internal; and b) external. The

internal micro level refers to the intra-organisational echelons, such as inbound and outbound supply chain performance. The *external micro level* refers to the inter-organisational supply chain performance, such as physical distribution and procurement between companies.

The macro level of supply chain performance consists also of two levels, namely: a) inner; and b) outer. The *inner macro level* refers to the industry and other industries. The *outer macro level* refers to society in a broader sense - that is, not necessarily following national borders, or limited to one society.

The external micro level connects to the inner macro level that creates the interface between the micro and macro levels of the bullwhip effect in operative, tactical and strategic supply chain performance. The interface bridges the current shortcomings and restrictions of the construct. It is further developed in the next section.

Extended Derivation and Broadened Positioning

		Environmental level	
		Micro	Macro
Supply Chain Performance	Upstream/Outer	<i>Reversed Bullwhip Effect</i>	<i>Societal Bullwhip Effect</i>
	Downstream/Inner	<i>Mainstream Bullwhip Effect</i>	<i>Industrial Bullwhip Effect</i>

Table 1. Extended Derivation and Broadened Positioning of the Bullwhip Effect.

Traditionally, the mainstream application and usage of the bullwhip effect construct is derived from the assumption that the downstream supply chain performance (e.g. operative and tactical) causes the effect of an increased performance upstream in supply chains. The mainstream construct of the bullwhip effect is also positioned at a micro level of the environment. In table 1, an extended derivation and broadened positioning of the construct is introduced.

Two principal components may serve as a framework to extend the derivation of, and to broaden the positioning of, the construct of the bullwhip effect, namely: a) environmental level and b) supply chain performance. The former (i.e. the environmental level) position the cause of the bullwhip effect at either micro or macro levels of the environment. The

latter (i.e. supply chain performance) derives from the effect to either produce an upstream/outer or downstream/inner increase in supply chain performance. These components and their dimensions reveal four different sub-constructs of the bullwhip effect as follows:

- ✓ *Mainstream Bullwhip Effect* - refers to the dominant application and usage of the construct. (e.g. Yu, Yan and Cheng; 2001; Chen, et al, 2000; Fransoo and Wouters, 2000; Kelle and Milne, 1999; McCullen and Towill, 2001; Jacobs, 2000; Metters, 1997; Lee, Padmanabhan and Whang, 1997a; 1997b). This means that the causes of decreased performance upstream in supply chains have their roots downstream. The effect is considered at the external micro level of the environment.

- ✓ *Reversed Bullwhip Effect* - refers to a non-mainstream application and usage of the construct (e.g. Svensson, 2003). This means that the causes of decreased supply performance downstream in supply chains have their roots upstream. The effect is considered at the internal micro level of the environment.
- ✓ *Industrial Bullwhip Effect* - refers to a revised view of the construct. This means that the causes of decreased performance within supply chains are at the industry level (i.e. inner macro level) - that is, beyond the supply chain itself. The effect is considered at the inner macro level, but should also be considered at both the internal and external micro levels of the environment (e.g. operative, tactical and strategic supply chain performance).
- ✓ *Societal Bullwhip Effect* - refers also to a revised view of the construct in relation the other effects, such as the industrial, the reversed and the

mainstream ones. It means that the causes of decreased performance within supply chains are at the societal level (i.e. outer macro level). The effect is considered at the outer macro level, but should also be considered at both the internal and external micro levels - as well as the inner macro level - of the environment (e.g. operative, tactical and strategic supply chain performance).

The typology or framework of the extended derivation and the broadened positioning of the bullwhip effect introduces a new setting for the bullwhip effect. It pushes the realm of the construct from a rather myopic and uniform context to an extensive and complex reality - where the cause and the effect may not be taken for granted - that is, a two-way view. What is the cause or the effect of a so-called bullwhip effect is not a matter of course. In other words, it may not always be affirmative that the cause of the bullwhip effect is

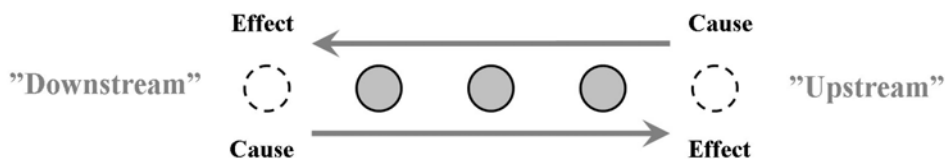


Figure 2. A Two-Way Approach of the Bullwhip Effect.

downstream and the effect of increased supply chain performance is upstream, and vice versa. It may be a combination in which the micro and macro environments interact (see Figure 1).

The mainstream and reversed bullwhip effects (see Figure 2) indicate that the cause-effect relationship of the construct is not always unidirectional. On the contrary, it appears to be a bi-directional relationship between cause and effect. On the one side, the cause of decreased performance may be downstream in the supply chain; on the other, it may be upstream in the supply chain. Therefore, the bullwhip effect construct should be seen as representing a two-way approach on a micro level of the environment. On the industrial and societal levels of the construct, the approach is unidirectional.

Managerial Implications

A framework of managerial implications is described in table 2. It provides an overview and summary of tentative types of bullwhip effects and supply chain performances. The four bullwhip effects are defined and their underlying driving forces are exemplified. In addition, the

importance to managers is highlighted and some preventive actions are proposed. Finally, the practical meaning and tentative areas of applications are suggested.

The table also provides some complementary illustrations to the previous discussion to extend and broaden the construct of bullwhip effect. It does not aspire to be complete, but rather a complement to the frame of reference on the construct and to be used in further explorations.

Concluding Thoughts

The interface now discussed between micro and macro levels in operative, tactical and strategic supply chain performance has contributed to an extended derivation of the bullwhip effect (see Figure 1). The introduced typology and framework of the bullwhip effect (see Tables 1 and 2) have contributed to broadening the positioning of the same construct. Figure 2 has illustrated that the bullwhip effect should be seen as bi-directional construct - at the micro level (i.e. the mainstream and reversed bullwhip effects). This is indicated by a bi-

directional relationship between the cause and effect of increased performance in different echelons of supply chains. Most important of all is that the causes and effects of the bullwhip effect have been addressed in a wider context, one that so

Table 2. Types of Bullwhip Effects - A Framework of Managerial Implications

Type of Bullwhip Effect(s)	Definition(s)	Driving force(s)	Importance to manager(s)	Preventive action(s)	Practical meaning(s)	Area(s) of Application
Mainstream	The causes of decreased supply chain performance are derived downstream.	<u>Downstream sources:</u> e.g. poor demand forecast updating, failing order batching, price fluctuation, wrong rationing and shortage gaming	<u>Impact on:</u> e.g. costs of inventory management, production planning, sales and corporate competitiveness in the marketplace	<u>Aim at:</u> e.g. reduced lead times, revision of reordering procedures, limitations of price fluctuations, planning and performance measurements	<u>The effect:</u> emphasized within a downstream supply chain context	e.g. Efficient Consumer Response (ECR) in the retail industry and Quick Response (QR) in the textile industry
Reversed	The causes of decreased supply chain performance are derived upstream.	<u>Upstream sources:</u> e.g. production incapacity, transport shortage, financial bottle necks, inflexible/ or single sourcing among suppliers and suppliers' suppliers etc.	<u>Impact on:</u> e.g. production planning, market sales, customer service, market shares and physical distribution	<u>Aim at:</u> e.g. quantity and quality assurance of supplies, e.g. multiple sourcing and contingency planning	<u>The effect:</u> emphasized within an upstream supply chain context	e.g. Just-In-Time (JIT) in the automotive industry and Third-Party Logistics (3PL)
Industrial	The causes of decreased supply chain performance are derived from the industry.	<u>Inner sources:</u> e.g. poor competition, insufficient cooperative and coordinating efforts of business operations	<u>Impact on:</u> e.g. industry competitiveness, financial exposure and other substituting industry products	<u>Aim at:</u> e.g. R&D, enabling technology, cooperation and competition in the industry, committed industry association and lobbying,	<u>The effect:</u> emphasized beyond the supply chain context within industries	e.g. Supply Chain Management (SCM) as an umbrella construct
Societal	The causes of decreased supply chain performance are derived from the society (e.g. region, country, group of countries or continent).	<u>Outer sources:</u> e.g. economic cycles, fluctuating purchasing power in the marketplace, changes in laws and regulations and governmental policy changes	<u>Impact on:</u> e.g. corporate profitability, investment decisions, shareholder value capital and strategic planning	<u>Aim at:</u> e.g. business intelligence, contingency planning, domestic and accurate information systems	<u>The effect:</u> emphasized beyond the industry within societies. (i.e. economic, political and business)	e.g. domestic, international and global economy/ finance/competition

far has been underestimated in literature.

However, further conceptualisation is required, as well as empirical support. The extended derivation and the broadened positioning of the bullwhip effect in the overall environment are of interest to practitioners, since they stress the importance of contextual factors in operative, tactical and strategic supply chain performance. The introduced derivation and positioning of the bullwhip effect construct reveal research potentials. One such principal potential could be if the exploration of the construct might consider the industrial and/or the societal environment at times when the bullwhip effect is studied in supply chains. This would lead to an increased understanding of the surrounding causes in the environment of the bullwhip effect.

(Received: 17 January 2007)

(Accepted: 1 April 2008)

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